International Journal of Metallurgical & Materials Science and Engineering (IJMMSE)
ISSN (P): 2278-2516; ISSN (E): 2278-2524
Vol. 9, Issue 1, Jun 2019, 1-6

A STUDY ON QUALITY AND CHARACTERISATION OF PLACER ILMENITES FROM PARTS OF EAST COAST OF INDIA, WITH REFERENCE TO ITS INDUSTRIAL APPLICABILITY

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ABSTRACT

Ilmenites from the East Coast of India, from deposits viz Kakinada, Bhimunipatnam, Srikurmam, and Chatrapur have been investigated for their Ore mineralogy and Geochemistry, with particular emphasis on their Industrial suitability. It is observed that ilmenites especially from these deposits except Kakinada deposit, exhibit extensive exsolutions like ilmeno-hematite, hemo-ilmenite, their intergrowths and combination of intergrowths. The impact of these exsolutions on industrial processing of these ilmenites have been discussed. Especially, the impact of high iron content in the form of hematite exsolutions on the industrial processing is brought out. While considering the detailed geochemistry, it is observed that TiO_2 content has been observed to occur in these deposits differently, Kakinada (51.04%-53.81%), Bhimunipatnam (46.12%-54.30%), Srikurmam (50.04%-52.05%), Chatrapur (50%-58.9%), whereas trace elements concentrations have been analysed especially elements like Co, V, Al, Cr, Mn etc., which are considered as of toxic nature in the preparation of synthetic rutile which is the important product for titanium metal production. The data on the occurrence of these trace elements can be used to take necessary precautions to design successful metallurgical process. Based on Ore mineralogical and Geochemical aspects it is felt that majority of the ilmenites from these deposits are more suitable for pigment manufacturing using chloride route which is more environmentally friendly.

KEY WORDS: Ilmenite, East Coast Placers, Chatrapur, Kakinada, Bhimunipatnam, Srikurmam, Geochemistry, Ore Mineralogy, Synthetic Rutile & Pigment

Received: Mar 14, 2019**; Accepted**: Apr 04, 2019; **Published**: Apr 16, 2019; **Paper Id**.: IJMMSEJUN20191

Original Article

INTRODUCTION

Placer deposits of India are of economic importance, the majority of the deposits found in the near shore environment. These are the detrital mineral remains, which were transported from their original source areas and deposited at the depositional sites. These have been formed by the mechanical concentration of detrital minerals and occur in beaches, rivers, dunes and offshore environments. Placer minerals are resistant to chemical breakdown and having high density. The East and West Coast beaches are characterised by placer minerals like Ilmenite, Garnet, Sillimanite, Rutile, Sphene, Zircon and Monazite.

Ilmenite, which is of black iron titanium oxide with composition $FeTiO_3$. It is a primary ore of titanium, which is an essential metal in this Modern age where technology is surpassing human life. All over the World Ilmenite is mined and mainly used to manufacture titanium oxide. As it is named after Ilmeniski Mountains in Russia, where it was discovered first time. Ilmenite with its magnetic property is used to separate from other mineral sands and also it can withstand extreme temperatures. As this titanium metal and alloys of it, are being

used in different applications like aerospace industry, gas turbines, cutting tools, pigments etc.

Ilmenites reserves of the World estimated around 2 billion tons, out of which 872 million tonnes are proved, and major reserves are present in China, Australia, India, South Africa, Brazil, Madagascar, and Norway. India is blessed with long coastline nearly 6000 km, along West and East Coasts where these Ilmenites are occurring as placer deposits.

Placer Ilmenites occur along the East Coast of India are present mostly in Andhra Pradesh, Orissa and Tamil Nadu. These three states which comprises of 253 million tonnes (IBM annual report, 2017) of estimated Ilmenite reserves.

Table 1: Ilmenite Resources of East Coast India

Andhra Pradesh	In million Tonnes	Orissa	In million Tonnes	Tamil Nadu	In million Tonnes
BhavanapaduHukumpet	10.18	Brahmagiri	37.98	Kudiraimozhi	22.86
Kakinada	13.84	Chatrapur	26.72	Teri	24.01
Kalingapatnam	5.80	Gopalpur	6.39	SattankulamTeris	41.26
Narsapur	2.92			Cuddalore-Pudupattuchavadi	4.67
Nizampatnam	19.26			Vayakallur	3.54
Srikurmam	8.60			Manavalakurichi	2.04
Visakhapatnam	2.88			Midalam	1.64
Amalapuram, Bapatla, chirala	10.39				
Vetapalem coast	5.31				
Total	**82.28**	**Total**	**71.09**	**Total**	**100.02**

Source: IBM annual report 2017

STUDY AREA

This study is mostly concerned with the deposits of Kakinada, Bhimunipatnam-Visakhapatnam, Srikurmam of Andhra Pradesh and Chatrapur of Orissa (Figure 1). Some work on mineralogical and geochemical aspects were carried out earlier on Visakhapatnam-Bhimunipatnam deposit (Sastry, 1987; Rao, 1983), Chatrapur placer deposit (Mukherjee, 1998: Sukumaram and Nambir, 1994) and Srikurmam (Jagannadha Rao, 2008). In the present study characterisation of these ilmenite deposits is made by Ore mineralogical and geochemical studies with emphasis towards their application in different industries.

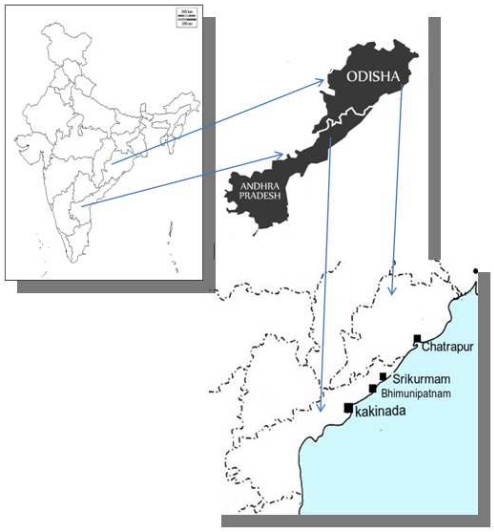


Figure 1: Study Area of the Map

METHODOLOGY

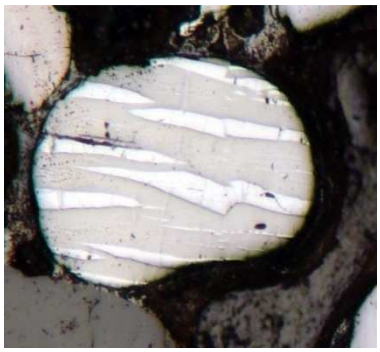
For ore mineralogical studies of Ilmenite, bulk sample is reduced to required quantity by standard sample reduction techniques. Heavy minerals were concentrated by bromoform and the magnetite was separated by hand magnet. The magnetite free samples were then run through the isodynamic separator set at 0.25amp to separate ilmenite and separation was repeated several times to ensure high purity ilmenite. Polished sections, made in araldite medium, were studied under Leica DMLP microscope for their ore mineralogical aspects. These pure Ilmenites were analysed by Atomic Absorption Spectrophotometer, Perkin Elmer make, Model – AS200 and ICP-MS for major and trace elements.

RESULTS

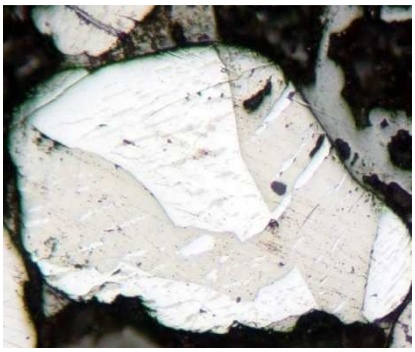
Ore Mineralogy

The Ore microscopic examination of ilmenite grains from Chatrapur revealed, that some grains having exsolutions mainly between the exolved phases of ilmenite-rutile, ilmenite-hematite, hematite-ilmenite. Many complex exolved phases are observed and also formation of lamellae with dominant hematite phase named as hemo-ilmenite, in the same way with ilmenite dominant phase termed as ilmeno-hematite, intergrowth lamellae of both Ilmenite and hematite phases are also observed.

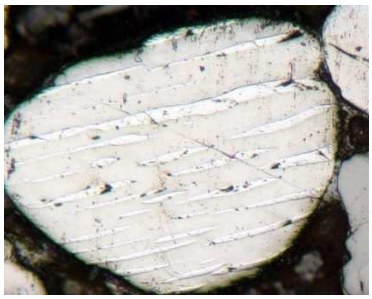
Ilmenites of Bhimunipatnam deposits show grain size of perfectly rounded to irregular (Jagannadha Rao, 2006). These show extensive features like exsolutions of hemo-ilmenite, ilmenite-hematite (Figure.2-e, f), and these ore mineralogical studies resemble to that of Cox Bazar (Sam Suddin Ahmed, 1992). Ilmenites of Chatrapur (Figure.2-a, b), Srikurmam (Figure.2-c, d) also have exsolutions formed by the mineral phases hematite-ilmenite, ilmenite-hematite, ilmenite-rutile etc., and for Kakinada deposit no exsolutions are present.



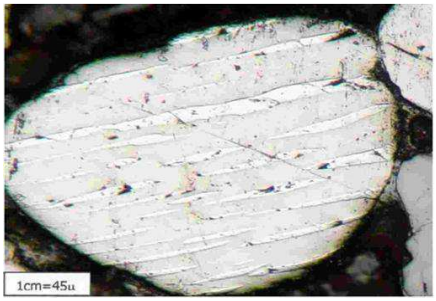
a. Lamellar Exolved Phases



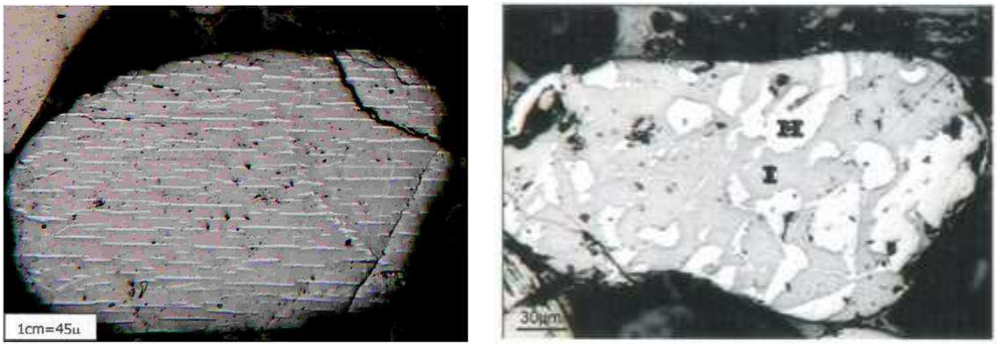
b. Irregular Exolved Phases



c. Simple Exsolutions



d. Banded Exsolutions



e. Myrmekitic Texture **f. Emulsion Texture**

Figure 2 a, b c, d, e, f: Exolved Phases of Ilmenites from Three Deposits

GEOCHEMISTRY

The Ilmenite samples from the study areas as represented in the Figure 1 were studied for major and trace elemental concentrations (in ppm) are shown in the Table-2.

Table 2: Chemical Analysis of Ilmenites (Major Radicals with wt.% and Trace Elements in ppm)

	Sample	TiO_2	SiO_2	Al_2O_3	Fe	MgO	Cr	Mn	V	Co	Ni	Zn	Cu
Kakinada deposit, Andhra Pradesh.	1	52.08	0.3	0.27	45.27	0.17	1177	1.07	4129	162	58	466	114
	2	52.96	0.5	0.25	46.81	0.19	1176	1.73	4129	159	60	467	111
	3	53.81	0.3	0.26	44.04	0.17	1179	2.01	4127	161	56	465	115
	4	51.04	0.4	0.25	45.18	0.18	1177	1.04	4131	163	59	468	112
	5	52.51	0.5	0.27	46.5	0.19	1179	1.43	4130	161	57	464	115
	Avg	52.48	0.4	0.26	45.56	0.18	1177.6	1.46	4129.2	161.2	58	466	113.4
Bhimunipatnam-Visakhapatnam, AP.													
	1	47.36	0.24	0.41	49.95	0.4	1568	1.27	3338	590	86	495	66
	2	48.18	0.5	0.28	49.28	0.2	1289	0.31	3271	211	170	273	37
	3	53.5	0.8	0.3	44.34	0.32	1067	1.13	1526	236	96	686	75
	4	47.84	0.4	0.44	45.1	0.34	1208	0.63	2393	311	192	526	42
	5	46.12	0.18	0.52	52.26	0.26	1021	0.87	1335	245	121	613	56
	Avg	48.6	0.424	0.39	48.186	0.304	1230.6	0.842	2372.6	318.6	133	518.6	55.2
Srikurmam deposit, Andhra Pradesh.													
	1	51.12	0.38	0.17	46.66	0.2	651	0.74	1302	319	46	697	67
	2	52.05	0.37	0.16	45.84	0.3	653	0.52	1304	320	49	694	65
	3	50.65	0.39	0.18	47.53	0.2	618	0.93	1303	316	45	698	68
	4	50.04	0.38	0.18	45.41	0.4	651	0.69	1300	320	45	695	65
	5	51.95	0.37	0.17	47.02	0.3	649	0.81	1300	315	47	696	68
	Avg	51.16	0.37	0.17	46.49	0.28	650	0.73	1301.8	318	46.4	696.4	66.6
Chatrapur deposit, Orissa.													
	1	58.9	0.22	0.44	45.7	0.5	416	1.14	1064	304	24	926	71
	2	52.4	0.32	0.56	42.1	0.6	548	0.96	1012	173	30	709	55
	3	50	0.41	0.5	42.8	0.1	567	0.95	1132	381	34	771	57
	4	52.6	0.61	0.63	44.1	0.41	325	0.97	1008	117	17	928	70
	5	53.1	0.52	0.24	43.7	0.33	323	0.98	999	150	18	957	72
	Avg	53.4	0.416	0.474	43.68	0.388	435.8	1	1043	225	24.6	858.2	65

The results indicate that TiO_2 varies 51.04%-53.81% in (Kakinada), 46.12%-54.30% in (Bhimunipatnam), 50.04%-52.05% in (Srikurmam) and 50%-58.9% in (Chatrapur). Total Iron (Fe) content results indicated as 44.04%-46.81% in (Kakinada), 44.10%-52.26% in (Bhimunipatnam) and earlier study by Jagannadha Rao (1985) also reported high iron content in Bhimunipatnam, 45.41%-47.53% in (Srikurmam), 42.1%-45.7% in (Chatrapur), and the remaining major elemental concentrations like SiO_2, Al_2O_3 and MgO are indicated in lower average values. The details are presented in the Table-2.

Trace elements namely Cr, Mn, V, Co, Ni, Zn and Cu are also studied and determined. In these trace elemental concentrations Vanadium recorded 4129 ppm in Kakinada, 3338 ppm in Bhimunipatnam, 1064ppm in Chatrapur and 1300 ppm in Srikurmam. Earlier study by Jagannadha Rao (2008) also reported high amount of Zinc in Srikurmam placer deposit. In the present study Zinc concentration varies from each deposit and high concentration of Zn is reported from Chatrapur deposit with 957 ppm. Cr values of Bhimunipatnam are almost 1568 ppm, 1177 ppm in Kakinada deposit and very low in Chatrapur deposit. Co, Mn and Ni contents are determined in the Table-2.

DISCUSSIONS

Titanium is one of the toughest and has the ability to withstand reactions from acids, chlorine gas by salt solutions as it is of high resistance substance. Mostly 95% of titanium production consumed is in the form of titanium dioxide in a white permanent pigment used in paints, paper, tooth paste and plastics. Titanium dioxide paints are of great reflectors of infrared radiation and used extensively by astronomers and in exterior paints. Also used in cement, gemstones and as strengthening filler in paper. Titanium alloys are used as protective cover metal for aircrafts, combat armours, naval ships, missiles and space crafts. As it has high tensile strength to withstand high temperatures, corrosion resistance and light weight. Titanium is also used in the Nano technology. Titanium is often alloyed with iron, manganese, molybdenum and with other metals. As our study areas reported that variations in the Titanium dioxide, and also variations in major radicals as shown in the Table-2.

Most of the Titanium is obtained from Ilmenite by purification. As ilmenites obtained in the study area are not having high titanium content, it is upgraded to synthetic rutile or slag by Chloride Process or Sulphate process (Manuel, 2014). Initially Ilmenites are upgraded to 70%-90% of TiO_2 by electro-smelting process and for further purification chloride or sulphate processes are used depending on the usage of industry and purity of titanium dioxide required. Depending on the availability of titanium dioxide present in the Ilmenite, appropriate process is initiated for its purification and upgrading which is used for different industrial uses.

The presence of exsolutions in these ilmenites will lower the quality and quantity of Ore, this exsolutions between the exolved phases of ilmeno-hematite, hemo-ilmenite, banded exsolutions which increase the quantity of iron in the ilmenite which leads to the decrease in the quality of ilmenite as well as the quantity of ore reserves. Chatrapur, Bhimunipatnam, and Srikurmam deposits are having extensive exsolutions, and no exsolutions are reported in the Kakinada deposit. TiO_2 of the study areas reported from Chatrapur, Kakinada, and Srikurmam shows little high TiO_2 percent and low iron content. In Bhimunipatnam it recorded less TiO_2 content and high total iron content than the theoretical formula of the Ilmenite (Deer, 1965). Even some earlier work carried out on ore mineralogy (Jagannadha Rao, 2006; Raju, 2018; Jagannadha Rao, 2018) had reported extensive exsolutions in the Bhimunipatnam-Visakhapatnam and Srikurmam deposits.

The geochemical data (Table-2) indicated that all the ilmenite deposits of the study area is most suitable for manufacturing of TiO_2 pigment. These deposits contain TiO_2 around (45%-55%), iron content (40%-45%), which high iron content can be considered as polluting agent and can consumes more chemicals in the manufacturing of TiO_2 or $TiCl_4$ (Manuel, 2014). Chloride process is applicable for these deposits, and also it is most preferred because of its efficiency and environmentally safe for preparing TiO_2 by Synthetic rutile (Bencher and Benilite process) or slag (Manuel, 2014). The presence of elements like Ca, P, V, Co, Cu, Ni etc., can affect the properties of pigment grade and considered as toxic

elements (Manuel, 2014) and will have negative impacts on the preparation of synthetic rutile and its quality (Akbar, 2012). All the elements like Ca, P, V, Co, Cu, and Ni occur as normal in these deposits. In Bhimunipatnam, trace elements like V, Co, Cu, Ni vary around 3300 ppm, 590 ppm, 66 ppm, 86 ppm (maximum) and for Srikurmam 1300 ppm, 300 ppm, 60 ppm, 45 ppm (maximum) and for Chatrapur deposit it varies about 1000 ppm, 300 ppm, 70ppm, 25 ppm (maximum) and for Kakinada deposit it varies about 4126 ppm, 161 ppm, 113 ppm, 58 ppm (maximum) respectively. Bhimunipatnam deposit consists of high amount of trace elements which will affect the properties of the grade of the pigment and sometimes very low economical implication, while the other three deposits Chatrapur, Kakinada, and Srikurmam are having an average amounts of trace elements which will have no effect in the pigment processing of the Ilmenite.

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